Renewable and Sustainable Energy Reviews 28 (2013) 881–889

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Factors determinant of biogas adoption in Bangladesh

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ARTICLE INFO

Article history:
Received 26 February 2013
Received in revised form
26 July 2013
Accepted 11 August 2013
Available online 13 September 2013

Keywords:
Determinants
Adoption
Biogas plants
Rural areas
Bangladesh

ABSTRACT

The major attempt of this paper is to examine the factors affecting the biogas technology adoption in rural areas in Bangladesh. The study was conducted by a survey method on respondents. Stratified random and purposive sampling techniques were applied for selecting 150 biogas users and 150 non-users. Data were collected through individual interviews by using structural questionnaire. A qualitative response model (Logistic regression model) was applied for examining the main factors influencing the biogas adoption. As a result, socio-economic factors play an important role in the respondents' behaviors toward biogas adoption. The empirical results indeed highlighted that year of education, income level, number of cattle, and women headed family have significant influences on the decision of biogas plant installation. Subsequently, increasing the level of education, empowering women, enhancing the yearly income and number of cattle are strategies likely to increase the adoption rate of biogas plants. Environmental, economic, social, and technological benefits were considered by the respondents while engaging in the biogas plant adoption. Households are also motivated toward biogas plant installation by Non Governmental Organizations (NGOs). A tiny motivation comes from Governmental Organizations (GOs), local government, electronic and print media. Therefore, raising the population awareness on the benefits of biogas plant installation through the existing channels of communication campaigns, provision of financial incentive, participation of print media and active attendances of Government institutions could extend the biogas technology in Bangladesh.

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http://dx.doi.org/10.1016/j.rser.2013.08.046

1. Introduction

Agriculture is a major driving force to promote the growth of developing countries [1]. These countries have indeed given more policy concentration toward agricultural production than other socio-economic and environmental issues. Whereas land degradation and climate change are still challenges for agriculture in most of the developing countries, other complications such as energy crisis has come to add to the existing problems, leading to a faster deregulation of the economic growth. It is acknowledged that energy is a soul power of economic growth as it affects livelihoods in terms of society, politics, and environment, including access to water, agricultural productivity, health and general issues [2]. As a result, provision of affordable, efficient, and reliable energy services with minimum effect on environment is very important. Developing countries normally depend on the fossil fuels and day by day, the rate of fossil use increases, leading to a large range of ecological and environmental problems [3].

Bangladesh is a small country with a huge population about 160 millions. Per capita electricity consumption is about 252 Kilo Watt per Hour (kwh), which is very low compared to other developing countries [4]. As a general picture, rural areas solely depend on the locally produced biomass energy while urban areas exclusively depend on the fossil fuels. Both types of energy supply are sources of various environmental problems. Considering the energy crisis and the environmental problems resulting from the current energy supply options, Bangladesh is very willing to explore alternative sources of energy. In this context, environment-friendly bio-energy production could be an interesting instrument with potentials of fulfillment about 10 percent of total energy [4]. Therefore, renewable sources could be applied for mitigating the existing energy crisis, and regarding the socio-economic features of Bangladesh the biogas produced from renewable sources could play a major role in meeting both energy and environmental problems.

Biogas is a clean gas consists of Methane (CH_4) by 60%–70% and Carbon dioxide (CO_2) by 30%–40% with the remainder being hydrogen sulfide and other trace gases [5]. Biogas has manifold advantages and successful application can result not only in generation of biogas and bio-fertilizer but also in other socio-economic and environmental benefits [6]. Besides its potentiality to contribute to the mitigation of greenhouse gas emission, biogas can help to reducing air pollution and improving the utilization of crop nutrients [7]. More interesting fact is that biogas can be produced from locally available raw materials and harnessed in controllable, containable and usable quantities [8]. Considering all these advantages, the rate of adoption of biogas plants is increasing encouraged by Government and non-government initiatives. However, very little is known about the diving forces determining the adoption of biogas in rural areas of Bangladesh. In the prospect that the biogas technology could be extended, research, in addition to explore better technologies, should also inform about the factors affecting and motivating households' decision to adopt biogas plants.

Many studies reported on the determinants of technologies adoption in rural areas. Nevertheless, it is difficult to specify the factors affecting the adoption of technologies in different parts of world due to differences in agro-ecological and socio-economic nature [9]. For instance, while the principal economic rationality assumption (the utility maximization objective of individual household) might stand for households everywhere, the specific attributes influencing the households' utility and their behaviors (adoption decisions) are very likely to be uniform from one place to another. The major attempt is therefore to determine the key factors affecting the adoption process of biogas plant in rural areas of Bangladesh.

2. Overview of the energy sector and biogas technology in Bangladesh

Bangladesh has several energy sources including fossil, solar, hydro, wind, geothermal, and bio fuels. These sources can be divided into three groups: traditional (biomass), commercial (non-biomass) and alternative sources (renewable energy). Normally used for cooking and heating, the share of traditional energy is more than 90% of the total energy used in rural areas and 35% of the total energy used in Bangladesh [10]. Commercial energy and renewable energy contribute up to 60%–65% and 2%–5% of the total energy used in Bangladesh, respectively [4]. The use of renewable energy has considerably increased in Bangladesh in recent years. Specially, adoption of biogas technology and solar power generation are significantly spreading across the rural areas.

Traditional energy sources refer to biomass which rank fourth position after oil, coal, and gas, in terms of contribution to the world total energy production [11]. It mainly comprises of tree (wood, twigs, leafs and plant residues), agricultural residues (paddy husk, bran, bagasse and jute stick), and livestock (animal dung and poultry litter). These sources are key role players for cooking and heating in Bangladesh, especially in rural areas. The overuse of biomass negatively affects on environment by increasing the CO_2 emission and greenhouse gases as well.

Natural gas is the major source of fossil fuels the Bangladesh with a share up to 75% of the total commercial energy [4]. Gas, diesel, furnace, coal, and hydro power contribute to the total power production in Bangladesh by 82.12%, 6.93%, 5.68%, 2.49%, and 2.78%, respectively [4]. Power sectors mostly depend on the fossil sources compared to other sources [4]. About 60% of the total gas has been applied to power generation activities in 2010 [12].

Bangladesh has a huge potential of renewable energy sources while few strategies to utilize these resources have been undertaken. In addition, Bangladesh is located between 20.30–26.38 degree and 88.04–92.44 degree of north and east latitude, respectively, which is an excellent location for solar utilization [12]. Few local Non-Government Organizations (NGOs) including *Grameen Shakti*, Bangladesh Rural Advancement Committee (BRAC), *Rahim Afrose*, etc. are committed to enlarge the solar technology activities throughout the remote areas in Bangladesh. In 2012, the State owned Infrastructure Development Company Limited (IDCOL) has supported the partners NGOs in order to set up 13,20,965 Solar Home Systems (SHSs), providing over 36.5 MW (MW) [13]. As well, Bangladesh has great potentials to produce electricity by using the wind energy. It has the world's largest sea beach along the Bay of Bengal. Yet, hydro energy generates up to 230 MW in South-Eastern part of Bangladesh [14].

More than 90% of the total fuel wood supply comes from homestead forest and other areas while the total biomass consumed per year is over 39 million tons of which about 50% come from the agricultural residues depriving the soil of organ matter and essential micro nutrients like Zinc, molybdenum, boron etc. If this trend is not changed, fertility will go down tremendously making the land barren in the next 50 to 100 years [15].

Biogas is a product of forming from biomass which is a clean combustible fuel. Cowdung, poultry litter and family wastages are major raw materials for biogas production. In Bangladesh, the biogas activities have begun since 1972. Government Organizations (GOs), NGOs, Research Organizations and Universities have been involved in this sector from the very beginning. Prof. Dr. Abdul Karim from Bangladesh Agricultural University was the pioneer researcher who established first two fixed dome biogas plants in the same University. Later on, the Local Government Engineering Department (LGED) and the Bangladesh Council of Scientific and Industrial Research (BCSIR) were involved in this technology to extend it all over the country. Finally Government

established a regulatory body called IDCOL for monitoring, evaluating, issuing, and distributing subsidies and credits to the biogas users.

The fund of IDCOL comes from different organizations, including World Bank, GEF, KfW, GTZ, SNV, ADB and IDB[2]. So far, BCSIR installed about 22,000 biogas plants from 1992 to 2003. IDCOL also constructed about 22,000 small scale biogas plants through National Domestic Biogas and Manure Program (NDBMP) up to 2012 [13]. Primarily, IDCOL has given more emphasis on solar energy followed by biogas activities since 1997. It has more than 30 partner organizations which are implemented the biogas plants in rural areas. IDCOL provides BDT[3] 9000 per plant as investment subsidy to the biogas users, following the specifications and standards set by IDCOL/SNV/KfW. *Grameen Shakti* is the largest partner organization of IDCOL which installed about 12,000 small scale biogas plants across Bangladesh. It has followed few rules and regulation for distributing the subsidies and loans to the biogas households [16].

Most family size (small scale) biogas plants promoted in Bangladesh have a bio-digestion capacity volume from 1.4 to 8 m^3. Cowdung is a major feed stock for biogas production compared to poultry litter, agro-industrial wastages and residues, crop residues and animal residues. Thus, Bangladesh has a huge potential to adopt the biogas technology over the country. The potentials of Bangladesh to produce 2.7 billion m^3 of gas can be obtained from 4 million small scale biogas plants, using the livestock resources which are equal to 1.5 million tons kerosene [17]. Despite its advantages and favorable conditions, Bangladesh is still far behind in terms of valuing its alternative energy sources, especially the biogas plants. To meet the ongoing energy crisis, initiatives need to be undertaken in order to enhance the use of renewable sources in general and biogas technology in particular. In this prospect, understanding the driving forces which determine the households' decision to adopt the biogas plant is a prerequisite.

3. Materials and methods

3.1. Study zone and database

The study was conducted in rural areas, well known to be agro-based with low energy consumption. A stratified random sampling technique was used for selecting the households to be surveyed. Mymensingh (central zone) from Dhaka division, Pabna (west zone) from Rajshahi division, Thakurgaon and Dinajpur (northern zone) from Rangpur division were selected and finally one or two sub-districts (locally called *Upazila*) were chosen from each district according to the availability of biogas plants as well as the number of potential biogas households. Then, the purposive random sampling technique was used to carry out samples of biogas users (households already using the biogas plants) and biogas non-users (households not using the biogas plants, either willing to do so, or not).

Primary data related to the household socio-demographic and economic characteristics, including the motivation of using biogas plants were collected from 300 households divided into two groups: 150 households categorized as “biogas producers and users” and the remaining 150 households categorized as “potential biogas users or biogas non-users”. The head of the household was the respondent.

The data collection was carried out through a household survey based on a questionnaire. A first draft of the questionnaire was designed according to the research objective and the required data as reported in the literature on technology adoption in general, and biogas adoption in particular. Then, this questionnaire was pre-tested during an exploratory survey organized in the study zone. Some focus group discussions with households and local key informants were also organized along with the exploratory survey to get insights on the main driving forces determining the adoption of biogas in rural areas in Bangladesh. From the preliminary results of this survey, the questionnaire was up-dated and later on, used for primary data collection from the biogas users and non-users in the selected areas from July to September 2011.

Data were analyzed by using statistical techniques (descriptive statistic, cross tabulation, frequency Tables, means *t*- test, and logistic regression) with STATA 10.1. Secondary data were collected from different Government offices, NGOs and private entrepreneurs who actively promoted the biogas activities in Bangladesh, Bangladesh Bureau of Statistics (BBS), Bangladesh Economic Review (BER), and scientific research papers.

3.2. Empirical modeling of biogas plants adoption

Adoption of biogas technology in this study is the dependant variable defined as production and consumption of biogas from a small-scale bio-digester by a household. The logistic model was applied to investigate the biogas technology adoption process. Both *logit* and *probit* are well recognized approaches in adoption studies [18]. The choice of whether to use a *probit* or *logit* model is a matter of computational convenience [19]. Logistic regression is used when the dependent variable is dichotomy and the independent variables are of any type. It applies Maximum Likelihood Estimation (MLE) after transforming the dependent variable into a *logit* variable [20]. It estimates the odds of a certain event occurring. The dependent variable is a *logit*, which is the natural log of the odds, that is:

$$\ln\left(\frac{P}{1-P}\right) = a + bX \tag{1}$$

Extracting P from this equation, it comes out that

$$P = \frac{e^{a+bX}}{1+e^{a+bX}} \tag{2}$$

where P is the probability of the event occurring, X are independent variables, e is the base of the natural logarithm and a and b are the parameters to be estimated by the model. The empirical form of the model used in the study is as follows:

$$\Pr Y = \frac{1}{1+e^{-(a+bX)}} \tag{3}$$

where Y is the logit for the dependent variable. The logistic prediction equation for the present study was:

$$\begin{aligned} Y &= ln(odds(event)) = ln(prob(event)/prob(nonevent)) \\ &= ln(prob(event)/[1-prob(event)] \\ &= b_0 + b_1X_1 + b_2X_2 + \dots\dots.. + b_nX_n \end{aligned} \tag{4}$$

Where b_0 is a constant term, X_1, X_2,…,X_n are independent variables likely to affect the probability of adopting the biogas technology, and b_1, b_2,…, b_n are the coefficients to be estimated. The dependent variable was modeled as: Y=adoption of biogas technology=$P(Y)$={*1* if the household chooses to produce and use biogas technology, and 0 otherwise}.

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[2] GEF=Global Environmental FacilityKfW=Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute), GTZ=Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation), SNV=Netherlands Development Agency, ADB=Asian Development Bank,IDB=Islamic Development Bank.

[3] 1 USDollar=78 BDT

Table 1
Definition of explanatory variables for biogas technology adoption model.

Variable	Type	Description
Age	Contin.	Age of household head in years
Education	Contin.	Educational level of household head in Years
Family size	Contin.	Total number of people in the household
Gender	Binary	Sex of household head (1=male; 0= female)
Farm size	Contin.	Total land area cultivated by the household in acre
Cattle	Contin.	Total number of cattle owned by household
Poultry	Contin.	Total number of poultry birds owned by household
Income	Contin.	Total yearly income (BDT)

Table 2
Explanatory variables with priory signs for biogas energy adoption model.

Variable	Expected sign
Age of household head in years	±
Educational level of household head in Years	+
Total number of people in the household	±
Gender of household head	±
Farm size in the household in acre	+
Total number of cattle owned by household	+
Total number of poultry birds owned by household	±
Total yearly income (TK)	+

3.3. Selection of the variables likely to explain adoption of biogas technology

Explanatory variables considered in the adoption process have often lacked a farm theoretical basis, possibly due to fact that households consider different issues beyond socio-economic incentives, including non-economic factors. In this study, the selection of the prospective variables that could affect the households' decision to adopt biogas plant was grounded in literature and fields experiences. The considerable amount of literature on adoption behavior reports that social, physical, economical, political and institutional factors are the core determinants of the adoption process [8,9,21–24]. The entire list of prospective determinants of biogas adoption is presented in Table 1.

As in most of the adoption studies, it is hypothesized in a first stage that socio-economic and demographic characteristics of households would play a role in the biogas technology adoption process. Then, in a second stage, specific assumptions regarding each variable listed in Table 2 were set as follows:

- *Age*: Age of household head is expected to have mixed (positive or negative) influences on the decision to adopt biogas plants. Older household heads could have higher economic status and though, higher capability to afford a biogas technology. On the other hand, aged men are less likely to accept innovation. They are indeed more likely to take decision on a risk adverse or even risk neutral basis, implying that they are not prepared to experiment a new thinking. The expected sign of aged person is an empirical question because while older farmers have experience and are better able to assess the characteristics of modern technology than young farmers, older farmers may be more risk averse than younger and have a lower likelihood of adopting new technology [21]. Thus, it might be difficult to conclude on the relationship between age and adoption of new technology [9] because, it is sensitive to variation in parameters and therefore the net effect of age on adoption cannot be determined *a prior*.
- *Education*: The number of years of education of household head is expected to have a positive relationship with adoption of new technology. More educated household heads were supposed to be less conservative, more exposed to sources of information and therefore more informed, knowledgeable, and aware on the negative effects of fossil fuels on environment [8]. They consider clean energy sources such as biogas on the grounds that it is more environmental friendly and more readily than their less educated counterparts.
- *Family size*: The size of household is expected to influence the adoption decision either positively or negatively. Larger family often has a larger number of working members and thus more labor for routine biogas operation and maintenance activities. Therefore, other things remaining same, larger households might have a higher probability of adoption of the biogas energy. However, larger households could also exert a heavier burden of dependence on the insufficient family resource to extend that there are hardly any savings available for investment in biogas technology. Under these circumstances, larger household size would negatively influence the decision to adopt biogas technology. If relative are viewed as a source of additional help, then farmers may try new practices [25]. Nevertheless, if they are viewed as dependents, then the household head may not be willing to adopt the new technology.
- *Gender*: We restricted gender to the discontinuous variable sex for modeling purposes. Thus gender of household head is expected to have either a positive or negative effect on biogas plants adoption. Since women dominate rural energy use at household level, it can be expected that households headed by women could have a higher probability of adopting biogas energy than their male counterparts [2,26]. Women are direct beneficiaries from the biogas uses. In contrast, men are assumed to be more concerned with achievement than women, meaning that men may be task oriented than women [27]. Men dominate control, access, ownership and decision making process regarding productive resources in the household and could directly influence investment decisions regarding biogas technology in Bangladesh.
- *Farm size*: The size of farm held by a household is expected to have a positive effect on the decision to adopt biogas. For a biogas unit to run effectively and efficiently, all three components (bio-digester, animal unit and fodder component) need to be close to each other for easy provision of feedstock to the bio-digester and effective monitoring of routine operational and maintenance activities. For this to be occurred, a household must have a minimum land threshold that can be accommodated. Based on this premise, it can therefore be expected that households with larger farm size would have a higher probability to adopting the biogas plant. Both theoretical and practical studies of adoption show a positive association between farm size and the probability and extend of adoption [28].
- *Cattle* and *Poultry*: The number of cattle and poultry birds owned by a household is likely to be an important factor in the biogas adoption process because they provide cowdung, the major substrate for small scale digester in Bangladesh. Overuse of poultry excreta would have negative influence of biogas production. The number of cattle and poultry birds owned by household was therefore used as an indicator of the available feed stock for the digesters. The availability of biomass input required in biogas plants and the availability of biogas technology and materials to build plants made them an attractive option [29]. It was thus expected that the higher the number of livestock is, the larger number of possibilities of adoption of biogas plants will be, implying a positive relationship.

– *Income*: Technology uptake is driven by household income. Households with a higher income level are more likely to adopt biogas technology than their poorer counterpart. Household income is thus expected to be positively correlated with the decision to adopt biogas technology.

Considering the previous assumptions, Table 2 summarizes the prospective explanatory variables with their expected signs in the biogas energy adoption model.

4. Results and discussion

4.1. Profile of biogas users and non-users

The mean values of the variables predicted to influence the household's decision to adopt biogas energy were computed and are shown in Table 3. Out of 300 biogas users and non-users, 290 were headed by men and remaining 10 by female. Age, family size, poultry bird were not significantly difference between biogas users and non-users. Biogas users had statistically ($P<0.05$) larger farm size, more income, more cattle and more year of education than their counterparts non-users. On the other hand, non-users of biogas technology had more poultry birds compared to the biogas users.

4.2. Reasons for adopting biogas plants

A good number of reasons actively motivate the household toward biogas adoption. These reasons encompass environment, economic, technical, and social aspects. Environmental reasons refer to health benefits, forestation, and soil fertility. Economic reasons are consisting of subsidies, credits, income generating and number of livestock. Technological reasons related to time and energy savings, fuel shortage, service provider and training. Finally, social reasons include neighbor plant owners' inspiration, NGOs motivation, advertisement attraction, and local government activities. Table 4 presents that environmental (63%) and economic (59%) benefits are the major reasons motivating households for adopting the biogas plant.

Biogas is a clean, smoke free and smooth gas that makes healthier environment for women and child during cooking time.

Women are getting more advantages from the biogas compared to men. About 66% of the biogas users were motivated by getting health benefits as the traditional cooking system (based on fossil fuels) is linked to many health problems, including respiratory diseases [30]. Indirectly, biogas helps at preventing deforestation in the rural areas [31]. About 62% of the respondents mentioned to be motivated toward biogas adoption for its forestation advantages. Bio-fertilizers that could be generated from biogas production are directly used in the agricultural field to increase the soil fertility [32]. As a matter of fact, 60% of the respondents are motivated to install a biogas plant for further gains in terms of soil fertility due to the use of bio-fertilizers. These environmental benefits are likely to ensure economic advantages since good health and soil fertility for instance can both contribute to improve agriculture production known to be the main activity in rural areas.

People are normally concerned about the costs and benefits issues of biogas technology. With this regards, biogas users behave properly where receiving more benefits. Economic issues were considered by 59% of the respondents, ranking the second motivating reasons for the adoption of biogas technology. Subsidy was mentioned by 60% of the respondents as crucial reason in taking the decision of biogas plant adoption. Most of the times, the adoption of a new technology requires incentives for encouraging the potential adopters. Social and technological issues are additional reasons motivating households toward biogas technology as mentioned by 24% and 26% of the respondents, respectively.

4.3. Inspiration of biogas technology adoption

Energy is a motor for many human activities. Therefore, it is acknowledged that an energy crisis is likely to bring up another crisis. Coping with the existing energy crisis in Bangladesh is not only an individual matter, but also involved public sectors.

In the Bangladeshi's perspective, two fixed dome biogas plant were installed in 1972. So far, about 40,000 small scale plants are installed and functioning across the country [13]. In recent years, National and International donors have come to be more and more active in this field of biogas plants.

At the household level, the decision whether to adopt biogas technology is a sole responsibility of the household's members (Could be the household head alone or, depending on the internal organization of each household, the household head and other members). This household's decision is however inspired from various sources such as NGOs, neighboring households, skilled person (e.g. Masons), society, local government, private entrepreneurs, and GOs. Fig. 1 presents the relative shares of each inspiration sources. About 90% of biogas users were motivated for adopting the biogas technology by NGOs. These NGOs indeed are actively working to promote renewable energy use with new technology in rural areas of Bangladesh. Neighbors played also an effective role in households' decision making process toward

Table 3
Descriptive statistics of selected the respondents.

Variable	Users	Non-users	Total sample
Age (year)	41.71	41.47	41.59
Farm size (acre)	3.56	2.77	3.24[a]
Family size(no.)	5.37	5.14	5.26
Gender	–	–	–
Male	140	150	290
Female	10		10
Education (year)	10.06	7.43	8.75[a]
Cattle (no)	4.48	3.29	4.33[a]
Poultry bird (0.00 no.)	3.46	4.08	461.24
Income (0.0000 BDT/year)	27.39	21.15	271060.3[a]

[a] Indicates that the difference between biogas users and non-users is statistically significant at $P<0.05$ (t-test used for the difference in mean).

Table 4
Motivating factors of biogas adoption in Bangladesh.

Factors	Motivating factors (%)	Average frequency (%)
Environmental	Health benefit (66); Forestation (62); Soil fertility (60)	63
Economic	Subsidy (60); Credit (48); Economic benefit (58); Number of livestock (69)	59
Technological	Time and energy savings(62); Fuel shortage (28); Service providers (6); Training (4)	26
Social	Neighbors plant owners (58); NGOs (47); Advertisement (0); Local Government (0)	24

biogas technology. Very often, neighboring households share their own ideas and experiences on new technologies. As a result, 48% of the respondents were inspired from neighbors' advice to take the decision to adopt biogas plants. Skilled manpower like masons also inspired the population in their own interest. These masons look for potential households who have sufficient number of cows or poultry birds. Their interest is to get commissions from biogas service providers for implementation of a plant. About 24% of the biogas users mentioned to be inspired by skilled manpower of biogas technology. GOs, local government, societal motivation and private entrepreneurs were also whispering to adopt the biogas plant. Given their very low shares as inspiration sources toward biogas technology adoption, local government, electronic and print media, private entrepreneurs were not playing notably well.

4.4. Factors influencing biogas energy adoption

Comparisons between adoption studies need to be made cautiously, using a rigorous conceptual framework and sufficient data, if reliable interpretations are to be achieved. Different objective methods lead to differing issues being examined and reported and the actors affecting adoption change over the technology diffusion cycle [33]. The estimated value fitted the observed data reasonably well for the logistic model (Table 5).

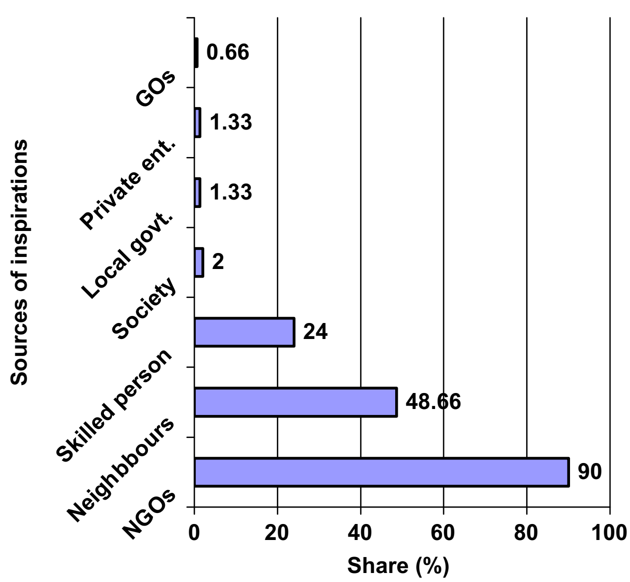

Fig. 1. Relative shares of the biogas technology inspiration sources.

Four Iterations were used for reaching the maximum log likelihood. Iterations stopped when the log likelihood was -174.61 with no any other differences between Iterations 3 and 4. The Likelihood Ratio (LR) Chi-square test was based on the assumption that at least one of the coefficients of the regression predictors was not equal to zero. The estimated LR chi2 value 59.73 indicated that the predictors' coefficients were different from zero. Moreover, the model was highly significant (Prob > chi^2=0.0000) although the Pseudo R^2 was relatively low (15%). This low coefficient of variation does not affect the quality of the model since it is a Mcfaddens' pseudo R-squared that does not have an equivalent meaning to the Ordinary Least Squares (OLS) R-square value [34] because it comes from binary variables.

Out of eight variables included in the model, four had statistically significant effects on the households' decision to adopt biogas technology. It comes from the empirical results that family size, age, farm size and number of poultry birds were statistically non- significant ($P > 0.10$). On the one hand, year of education of household head, number of cattle and family income were positively correlated with adopting biogas plants at 1% ($P < 0.01$), 5% ($0.01 < P < 0.05$), and 10% ($0.05 < P < 0.10$) statistic significance levels, respectively. On the other hand, gender of family head was negatively correlated with adopting biogas technology at 10% ($0.05 < P < 0.10$) statistic significance level. These results highlight that the household's socio-economic characteristics could be a real source of information on the reasons why households decide whether to adopt biogas technology or not.

Many programs aiming to promote a given technology have tended to focus more on the technical aspects of the disseminated technology. However, this study shows that socio-economic characteristics of the target beneficiaries are crucial in the popularization of new technology such as the biogas one.

A number of studies on technology adoption suggested that barriers to the popularization of a new technology include technical, economic, socio-demographic, institutional and political constraints. The development and management of biogas technology are far from a purely technical question and almost always involve economic and social problems as well as human behavior characteristics [35].

Gender relationships matter a lot in the ownership, management, use, and control of household's assets which influence the decision making processes. Based on gender, two types of household heads (male headed and female headed) have been seen in Bangladesh. Most of the times, males dominate the decision making processes within and over the family matters compared to female counterpart. Sometimes, both male and female are taking the decision through discussions. Beside, female are often

Table 5
Logistic regression estimates of biogas energy adoption model.

Variable (I)	Coefficient (II)	Standard error (III)	Odds ratio (IV)	Coefficient from odd ratio (V)=(IV−1)
Constant	−1.128	1.11	0.68	−0.318
Gender	−1.576	0.85	0.20	−0.799*
Education	0.170	0.03	1.186	0.186***
Age	0.003	0.01	1.003	0.003
Family size	−0.012	0.08	0.988	−0.011
Farm size	0.055	0.05	1.057	0.057
Cattle	0.107	0.05	1.113	0.114**
Poultry (,00 no)	−0.019	0.03	0.980	−0.019
Income (,0000 BDT)	0.024	0.01	1.024	0.024*
Model summary	Log likelihood = −174.61 LR chi^2=59.73 Prob > chi^2=0.000 Pseudo R^2=0.146% of total correct prediction=98.3% (295 households out of 300)			

* significant level at 10% ($0.05 < p < 0.10$).
** significant level at 5% ($0.01 < p < 0.05$).
*** significant level at 1% ($p < 0.01$).

devoted to inside family activities compared to male. Regardless to the type of the household, the head plays a key role in the decision making processes. He or she has the "final word" regarding the resources allocation, use, and management.

Though negatively correlated with the likelihood of adopting biogas energy, sex of the household head, a proxy variable for gender influence on the decision to adopt, was significant at 10% ($0.05<P<0.10$) statistical level with an estimated coefficient -0.799 to exponential antilog values meant of odd ratio 0.206; implying households are distinctly encouraged for adoption biogas technology. This particularly encouraging development as regards the promotion of biogas technology, female has at least access to and control of biogas resources, yet provides most of the labor required for production of biogas from female apart. Recognizing that women are more likely to engage themselves into the biogas plant adoption process than their male counterparts can be particularly instrumental in targeting women's organization for promoting biogas technology [8].

The logistic regression results revealed that the year of education of household head was positively correlated with the biogas adoption at 1% ($P<0.01$) statistical level of significance. Gujarati [36] stated that *in general, if you take the antilog of the jth slope coefficient* (*in case there is more than one regressor in the model*), *subtract* 1 *from it, and multiply the results by 100, you will get the percentage change in the odd for a unit increase in the jth regressor*. Accordingly, the likelihood of biogas technology adoption increase by 18.6% with one year increase of education. Moreover, there was statistically significant means difference of education level between users and non-users groups of biogas technology. Indeed, the level of education of biogas users and non-users were 10.06 years and 7.43 years, respectively (Table 3). These results are quite similar to some other adoption studies [25,28,21,37] which also reported a positive correlation between year of education and probability of biogas technology adoption. Nevertheless, some previous findings contrast this result by stating that education and new technology adoption are uncorrelated in Uganda and Bangladesh [8,35]. In the case of biogas, education is however likely to ensure a better understanding of indirect benefits (health gains, time and energy savings for instance) linked to the use of biogas technology.

Age of the household head was found to have a non-significant and positive relationship with biogas technology adoption as well as it was found no means difference of age between biogas users and non-users groups (Table 3). Although non-significant, this positive relationship reveals that aged household heads have good or better experience, are more likely to have available money as savings, certain label of space for biogas digester implementation, and therefore, are likely to adopt the biogas technology. This result does not support the findings of [24] and [8] in Burkina Faso and Uganda, respectively, who reported that farmer's age was negatively related to the probability of adoption biogas technology, meaning that older people are more risk averse and less willingness to take on new innovations.

The mean value of family or household size (5.26) was not notably different to the national average value of household size which is 5.00 persons [12]. However, family size had a negative relationship with the adoption of biogas technology, but not statistically significant. The coefficient, odd ratio and the coefficient form odd ratio of family size are -0.012, 0.988 and -0.011, respectively. This result indicates that one unit increase of biogas adoption is associated to 1% decreased of family member. This is contradictory to the findings of [8] who indicated that household size and biogas adoption have significantly positive inter-relationship. Besides, most of the family size digesters in developing countries have a common characteristic: the combination of biogas producers and biogas consumers whereby family members produce biogas and they consume what they have produced, implying a pair of contradictions: the interest of producer and the interest of consumer [6]. Biogas users assessed that labor needed in the routine operation and maintenance of the digester is especially important when the producers and consumers are combined and therefore a large family becomes a source of labor for tasks. The present study found that only 0.38 hour per day is needed for preparing the raw materials and producing the gas, and women and female child were given the certain labor for producing the gas.

Given the space requirement of biogas technology in terms of area for installing the biogas plants as well as providing pastures for the cattle and poultry birds expected to provide feed stock for biogas production, the area of land owned by the household becomes a crucial factor in the adoption of biogas technology. The average farm sizes were 3.56 and 2.77 acres for biogas users and non-users, respectively. The average national household farm area is 1.44 acres which is much lower than the average farm size of biogas users and non-users [38]. An integrated biogas unit normally comprises the biogas plant, the animal unit for provision of the substrate and the fodder unit to sustain the animal unit. All this require considerable space for the biogas unit to operate effectively and efficiently. For a biogas plant to operate economically, kitchen, animal shed, for dung generation, slurry compost pit and digester must all be close together in order to reduce costs [39].Considering the current structure and farm size in rural areas of Bangladesh, increasing one acre of farm size increased the likelihood of a household to adopt biogas technology by 6% (Table 5).

An increase of one number of cattle owned by household increased the likelihood of a household to adopt biogas technology by 11% at 5% ($0.01<P<0.05$) statistical level of significance (Table 5). Cowdung from cattle are one of the main sources of raw materials for biogas production in Bangladesh. Other sources like, poultry litter, crop residues, industrial residues and municipalities wastages are available. But there is no mechanism of taking the proper decision for collecting or using these additional sources for biogas production. Selecting the size of biogas plant to be installed depends on the number of persons to be served or the quantity of cowdung available and stress that selection of unsuitable bio digester capacity that does not match the availability of the cowdung renders the biogas technology uneconomical [5]. Two heads of cattle per household per day were adequate for gas production from family size digester [40]. The study found that the average number of cattle owned by a household was 4.48 for biogas users and 3.29 for biogas non-users (Table 3). Minimum 20 kg of animal dung/day (cattle, poultry, pigs, buffalos) are needed for continuing a small scale domestic biogas digester [41]. For a biogas plant, the daily input of dung is required by 6 kg per m^3 [42]. The present study found that the biogas users and non-users collected by 91 kg and 80 kg of cowdung, respectively. Mostly farmers reared the cross-breed cattle for producing the biogas.

Poultry industry has been flourishing across the country as well as the litter from poultry birds created a lot of social problems due to its odor in the locality. This could have been mitigated by the implementation of a small scale biogas plant in the same area. Biogas is indeed totally odor free and the liquid litter usable for improving soil fertility, especially in acidic soil. Yet, the number of poultry birds had no statistical influence on the decision to adopt the biogas plant. Adoption of biogas plants by using of poultry litter is still lacking information and motivation process in rural areas of Bangladesh.

The household's income was found to be among the key factors determining the adoption decision with a positive influence on the behavior toward the biogas technology. Thus, the logistic

regression model suggested that when the household's income level increased by 10,000 BDT per year, the likelihood to adopt the biogas plant increased by 2.4% at 10% ($0.05 < P < 0.10$) statistical level of significance (Table 5). Other studies have shown similar results with [43] stressing the impact of household's income on the choice of cooking fuel. The most probable effect of the income of household on adoption of biogas energy is the financial ability to install a digester system, which is often cited as the single most important factor determining whether a household adopts biogas energy. The initial investment is usually considered high to be afforded by a rural household and therefore, biogas digesters remain the privilege of relatively wealthier household in Uganda [8]. In Bangladesh, initial investment are also considered high but IDCOL issued a certain level of subsidy as well as NGO offered soft loan to rural households for reducing, to some extent, the initial high investment cost. Thus, household did not feel any monitory complexity during the plant implementation period.

5. Non-users perception of biogas technology

Potential biogas users are described as having at least three cows or three hundred poultry birds. The sample of households viewed as potential biogas users was selected from the neighbors of biogas users. They had opportunity to observe thoroughly the nature, longibility, advantages and disadvantages of a biogas plant. It was found that 88% of potential biogas users responded to be well aware of the existing biogas technology. Besides, an interesting result was that 81% of the potential users believed in biogas technology. The average year of education of potential users was about 8 years. Accordingly, they are likely to have the capability to access based on their own knowledge and perspective that the biogas plant is an interesting alternative energy source, including a large range of environmental, economic, social and technological benefits. Nevertheless, the high initial investment cost was the major barrier for adapting the biogas technology as mentioned by 78% of the potential users.

The average initial investment cost was 30 thousand BDT per plant. Given this high cost, it is possible for households willing to adopt the biogas plant to get subsidy and credit facilities. Yet, very few households are not interested in getting credit. This unwillingness toward the credit might be due to the fact that Bangladesh is a Muslim oriented country where interest rate on credit is not religiously accepted.

Cowdung or poultry litter are the main raw materials for preparing the biogas. Whether the gas is produced or not the users have to clean the substrates every day. This is an additional constraint responded by 38% load to regular use of raw materials. But still, it is matter of few minutes for shifting the collecting substrates from ground to digester hole. In sum, in the potential users prospect, it is generally recognized that biogas has a lot of benefits with tiny constraints. Indeed, all (100%) the potentials users recognized that biogas has multi-dimensional advantages while 87% of them were already willing and committed to adopt a biogas plant.

6. Conclusion

The main purpose of this study is to analyze the factors affecting the adoption of biogas technology in rural areas in Bangladesh. Biogas offers a good potential energy option through its several advantages. A logistic regression model used to analyze the household's adoption behavior toward biogas technology showed that several socio-economic factors matter in household's decision to adopt biogas plant.

On the one hand, the main factors identified as positively promoting the adoption of biogas technology are education, number of cattle, family income, family size and age. On the other hand, the main factors negatively correlated with the household's decision to adopt biogas technology are gender, and number of poultry birds. Education plays a very important role in the biogas plants adoption process as the more the household's head is educated, the more this household is likely to adopt biogas technology. The number of cattle belonging to the household is another core component of producing biogas. Female headed households have more interest in taking the decision to use biogas plants. Regarding the initial investments required, income is also a determining factor in the adoption process of biogas technology within the household.

United Nations is committed to promote sustainable renewable energy by adopting new arrangement on subsidies, taxes, and some other policies. The existing subsidy and flat credit system can be continued for a standard level where men can have seen visible incentives offered from government sides, and public advertisement of renewable energy as well as biogas technology could broadcast to the rural people. Thus, electronic and print media could help to spreading the technology throughout the country. Local government and local elite could also support the expanding of the biogas technology. They could grow the public attention on the existing energy problem which could be solved by adopting the biogas technology.

Despite its huge potential and numerous benefits, the significant role of renewable energy still lags behind the ambitious claims for it due to the initially high investment costs, concerns about local impacts, lack of research findings and poor institutional and economic arrangements [44]. However, local awareness of the benefits of biogas and willingness to adapt combined with availability of subsidies as well as soft loan to enable the installation of the biogas plant, stand out for the most important factors contributing to a successful large-scale-uptake of the technology.

Acknowledgments

The authors are grateful to the German Academic Exchange Service (DAAD) for financing this research. Thanks to the anonymous reviewers for their relevant suggestions and comments.

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